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Effectiveness of Cardiac Simulator on the Acquirement of Cardiac Auscultatory Skills of Medical Students

Wpływ symulatora kardiologicznego na nabycie umiejętności osłuchowych przez studentów medycyny

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Abstract

Background. Cardiac simulators have been developed as an alternative training model in order to improve the cardiac auscultation skills of medical students. The effectiveness of the cardiac simulator's use in cardiac auscultatory training is presently not yet well established.

Objectives. The authors aimed to investigate whether the use of a cardiac simulator can improve the auscultation skills of medical students.

Material and Methods. The students taking the auscultation training on the cardiac simulator were grouped as Group A and the students not taking the auscultation training on the cardiac simulator were grouped as Group B (before). The students in Group B (before) were grouped as Group B (after) after receiving the auscultation training on the cardiac simulator. The percentages of accurate diagnoses for the tested heart murmurs were compared between Group A and Group B (before), and between Group B (before) and Group B (after).

Results. The rate of making correct diagnoses of normal heart sounds was similar in all the groups (Group A, Group B (before), and Group B (after)). By contrast, the percentage of accurate diagnoses for the tested heart murmurs was notably improved among the students in Group A with respect to Group B (before) ($p < 0.01$). Similarly, the rate of correct diagnoses for the tested heart murmurs was markedly higher among the students in Group B (after) than in Group B (before) ($p < 0.01$).

Conclusions. The use of a cardiac simulator as a training tool can improve the auscultation skills of medical students quickly and efficiently (Adv Clin Exp Med 2012, 21, 6, 791–798).

Key words: cardiac simulator, auscultation skills, medical training.

Streszczenie

Wprowadzenie. Symulatory kardiologiczne służą jako alternatywny model szkolenia w celu poprawy umiejętności osłuchiwania serca przez studentów medycyny. Skuteczność symulatora kardiologicznego jako pomocy dydaktycznej w szkoleniu osłuchiwania serca nie została jeszcze w pełni ustalona.

Cel pracy. Autorzy mieli na celu zbadać, czy użycie symulatora kardiologicznego może poprawić umiejętności osłuchiwania serca przez studentów medycyny.

Materiał i metody. Studenci biorący udział w szkoleniu osłuchiwania serca za pomocą symulatora zostali włączeni do grupy A. Studenci niebiorący udziału w szkoleniu osłuchiwania serca za pomocą symulatora zostali włączeni do grupy B (przed). Studenci z grupy B (przed) zostali włączeni do grupy B (po) po odbyciu szkolenia osłuchiwania serca za pomocą symulatora. Odsetek poprawnych rozpoznań badanych szmerów serca porównywano między grupą A i grupą B (przed) oraz między grupą B (przed) i grupą B (po).

Wyniki. Odsetek stawiania poprawnych diagnoz normalnych tonów serca był podobny we wszystkich grupach; grupa A, grupa B (przed) i grupa B (po). Odsetek poprawnych rozpoznań dla badanych szmerów serca znacznie się

zwiększył wśród studentów w grupie A w odniesieniu do grupy B (przed) ($p < 0,01$). Podobnie odsetek poprawnych rozpoznań badanych szmerów serca był znacznie większy wśród studentów w grupie B (po) niż w grupie B (przed) ($p < 0,01$).

Wnioski. Wykorzystanie symulatora kardiologicznego jako pomocy dydaktycznej może szybko i sprawnie poprawić umiejętności osłuchiwania serca przez studentów medycyny (*Adv Clin Exp Med* 2012, 21, 6, 791–798).

Słowa kluczowe: symulator serca, umiejętności osłuchiwania, medyczny kurs szkoleniowy.

Ideal medical education is expected to have medical students acquire the skills of physical examination and use them effectively during their stay in medical school and after their graduation. However, the availability of patients with physical exam findings identifying a particular disease is unfortunately limited in several places [1]. In addition, the time allocated to bedside and physical examinations of patients has been reduced with the development of high-tech health technologies; consequently, medical students have fewer chances and less time to improve their skills of physical examination during their stay in medical schools. Cardiac auscultation is clearly an inevitable part of a physical examination in the diagnosis of heart diseases [2, 3]. However, medical students' acquisition of cardiac auscultatory skills during their routine medical training is not competent in general [4, 5]. The accessibility of patients with basic cardiac murmurs might be inadequate and the number of educators teaching cardiac auscultatory skills can also be few while the number of students taking cardiac auscultatory training might be excessively high. Nevertheless, the major drawback in cardiac auscultatory training is the inadequate time allocated for the teaching of necessary skills. The use of a simulator can minimize this setback in cardiac auscultatory training.

Cardiac simulators have been developed as an alternative training model in order to improve the cardiac auscultatory skills of medical students [6, 7]. The use of cardiac simulators can become a main training tool, particularly in medical schools with an inadequate number of patients. Utilization of cardiac simulators for improving cardiac auscultatory skills was started at the end of the 1960s. For this purpose, problem-based learning models, electronic stethoscopes and computer programs have been built and used up to today [8–10]. Nevertheless, the effectiveness of cardiac simulators in cardiac auscultatory training is controversial. While some studies show that the use of them improves cardiac auscultatory skills [10–12], others indicate that the use of them does not develop auscultatory skills [13, 14]. Consequently, the effectiveness of cardiac simulator use in cardiac auscultatory training is not yet well established presently. Therefore, in the present study the authors aimed to investigate whether the use of an auscultation

model capable of generating heart murmurs near to real strengthens the cardiac auscultatory skills of medical students.

Material and Methods

In the present study, 130 fifth-year medical students attending their cardiology internship at the Department of Cardiology during the semesters of 2009–2010 and 2010–2011 and 60 patients receiving treatment at the same department were prospectively included. Each patient in the present study was auscultated by 8–10 students doing their cardiology internship as part of their medical education (each cardiology internship group consisted of 8–10 students). The students were asked to auscultate the patients using their own stethoscope (3M™ Littmann® Classic II S.E. Stethoscope), 49 patients with murmurs owing to mitral stenosis, aortic insufficiency, pulmonary artery stenosis or ventricular septal defect and 11 patients with normal heart sounds and no murmurs. The main features of students and patients enrolled in the study are illustrated in Table 1. While patients with prominent murmurs were included in the current study, patients with mild murmurs were excluded from the present study. Prominent murmurs were defined as murmurs greater than 1 according to Levine's scale. Each student was allowed to auscultate only the patients arriving at the hospital during his/her cardiology internship. Both the students and the patients included in the current study were informed as to the nature of the study and their written consent was also obtained. The present patients were picked among the patients diagnosed with cardiac pathologies detected echocardiographically. Auscultation training was given to the medical students by a cardiology specialist during a 2h lecture using an auscultation model. The medical students auscultated their patients right after they had completed their cardiac auscultatory training program. During the training, the students were allowed to auscultate various heart sounds and murmurs generated by the model. The students taking the auscultation training on the cardiac simulator were designated as Group A and the students not taking the auscultation training on the cardiac simulator were

Table 1. Main features of students and patients enrolled in the study**Tabela 1.** Główne cechy studentów i pacjentów włączonych do badania

Students (Studenci) (n = 130)	Mean $\pm$ SD (Średnia $\pm$ SD)
age (years)	22.3 $\pm$ 3.7
gender (male) (n, %)	80 (61.5)
Patients (Pacjenci) (n = 60)	
age (years)	67.3 $\pm$ 8.7
gender (male) (n, %)	42 (70)
cardiac murmurs (n, %)	
normal heart sounds	11 (18.4)
mitral stenosis	14 (23.3)
aortic insufficiency	14 (23.3)
pulmonary artery stenosis	14 (23.3)
ventricular septal defect	7 (11.7)

designated as Group B (before). The students in Group B (before) did not receive any training other than routine theoretical and practical training during a cardiology internship. The students were randomly divided into these groups according to the last digit of their internship number. The students whose internship number ending with an odd digit were grouped as Group A and the students whose internship number ending with even digits were grouped as Group B (before). The students in Group B (before) were asked to auscultate the patients once again after receiving the auscultation training on the auscultation model. These students were then designated as Group B (after). Moreover, each student was asked to auscultate each of his/her patients within 10 minutes and to fill out the forms containing various heart murmurs right after the auscultation. The rate of correct diagnosis for given murmurs was compared between Group A and Group B (before), and between Group B (before) and Group B (after).

The auscultation model used in the present study was able to generate heart sounds and murmurs remotely controllable with the help of a remote stethoscope (NASCO auscultation trainer and smartscope™). The model was designed to produce discrete heart sounds and murmurs pertaining to 12 different conditions (normal, aortic regurgitation, pulmonary artery stenosis, mitral stenosis, holosystolic, mid-systolic, S3 gallop, S4 gallop, systolic click, atrial septal defect, patent ductus arteriosus and ventricular septal defect) on its anterior chest wall at six different sites. The model was able to imitate heart murmurs near to real quality and to generate the murmurs on the area very like to real human anatomy.

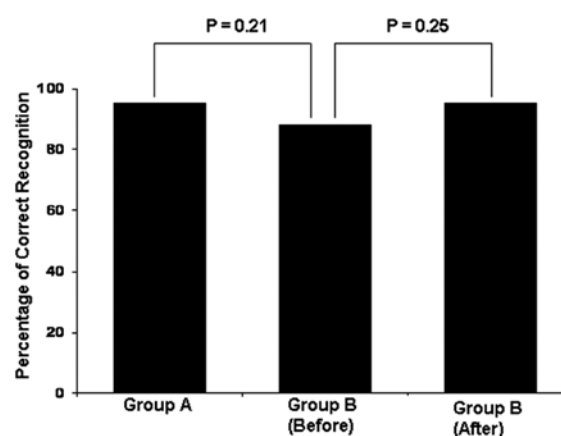
Statistical Analysis

Continuous variables were stated as mean $\pm$ SD; categorical variables were expressed as percentages. The comparisons between Group A and Group B (before) were done using a Chi-square test. The McNemar test was used to compare Group B (before) and Group B (after). A $p < 0.05$ was considered to be statistically significant. Statistical analyses were performed using SPSS 16.0 (SPSS Inc., Chicago, IL).

Results

Normal Heart Sounds

Eighty-four students auscultated 11 patients with normal heart sounds. Half of the students ($n = 42$) were in Group A and the other half ($n = 42$) belonged to Group B (before). The rate of making correct diagnoses of normal heart sounds was higher in all the groups; Group A, Group B (before), and Group B (after). Moreover, the authors noted no significant difference between Group A and Group B (before), and between Group B (before) and Group B (after) ($p > 0.05$) concerning the rate of making correct diagnoses of normal heart sounds (Fig. 1).

**Fig. 1.** Normal heart sounds**Ryc. 1.** Prawidłowy ton serca

Mitral Stenosis

A total of 116 students auscultated 14 patients diagnosed with mitral stenosis (MS). Half of the students ($n = 58$) were in Group A and the other half ($n = 58$) belonged to Group B (before). The rate of precise identification for MS murmur was markedly higher among the students in Group A compared to those in Group B (before) (48.3% vs. 18.9%, $p < 0.001$). Likewise, the rate of

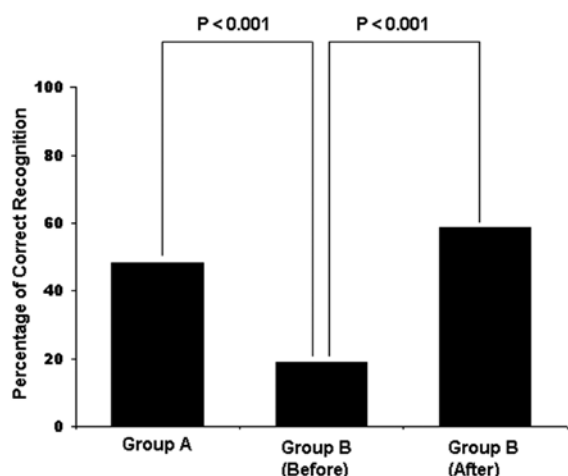


Fig. 2. Mitral stenosis

Ryc. 2. Zwężenie zastawki dwudzielnej

precise identification for MS murmur was significantly higher among the students in Group B (after) in comparison to those in Group B (before) (58.6% vs. 18.9%, $p < 0.001$) (Fig. 2).

Aortic Insufficiency

Similarly, a total of 110 students auscultated 14 patients diagnosed with aortic insufficiency (AI). Half of the students ($n = 55$) were in Group A and the other half ($n = 55$) belonged to Group B (before). The rate of precise identification for AI murmur was noticeably higher among the students in Group A compared to those in Group B (before) (50.9% vs. 21.8%, $p = 0.001$). Likewise, the rate of precise identification for AI murmur was significantly higher among the students in Group B (after) in comparison to those in Group B (before) (56.3% vs. 21.8%, $p < 0.001$) (Fig. 3).

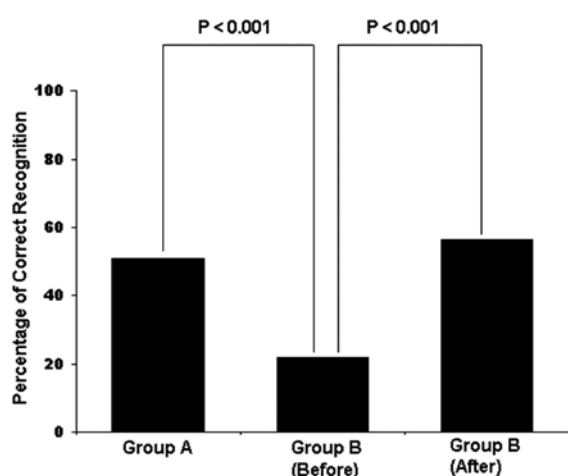


Fig. 3. Aortic insufficiency

Ryc. 3. Niewydolność aorty

Pulmonary Artery Stenosis

Likewise, a total of 120 students auscultated 14 patients diagnosed with pulmonary artery stenosis (PAS). Half of the students ($n = 60$) were in Group A and the other half ($n = 60$) belonged to Group B (before). The rate of precise identification for PAS murmur was considerably higher among the students in Group A compared to those in Group B (before) (76.6% vs. 45%, $p < 0.001$). The rate of precise identification for PAS murmur was also notably elevated among the students in Group B (after) in comparison to those in Group B (before) (88.3% vs. 45%, $p < 0.001$) (Fig. 4).

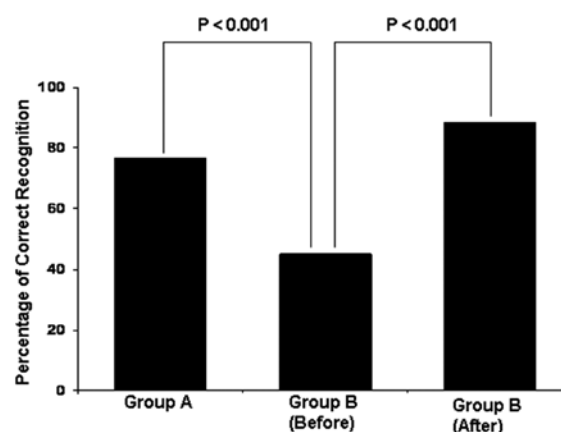


Fig. 4. Pulmonary aortic stenosis

Ryc. 4. Zwężenie aorty płuc

Ventricular Septal Defect

For the study of this defect, 100 students auscultated 7 patients diagnosed with ventricular septal defect (VSD). Half of the students ($n = 50$) were in Group A and the other half ($n = 50$) belonged to Group B (before). The rate of precise identification for VSD murmur was substantially higher among the students in Group A compared to those in Group B (before) (66% vs. 32%, $p = 0.001$). The rate of precise identification for VSD murmur was notably increased as well among the students in Group B (after) in comparison to those in Group B (before) (72% vs. 32%, $p < 0.001$) (Fig. 5).

Systolic Murmur

A total of 220 auscultations were performed on 21 patients with systolic murmur owing to the presence of PAS or VSD. Half of the auscultations ($n = 110$) were performed by the students in Group A and the other half ($n = 110$) were carried out by the students in Group B (before). The rate of making correct diagnoses for systolic

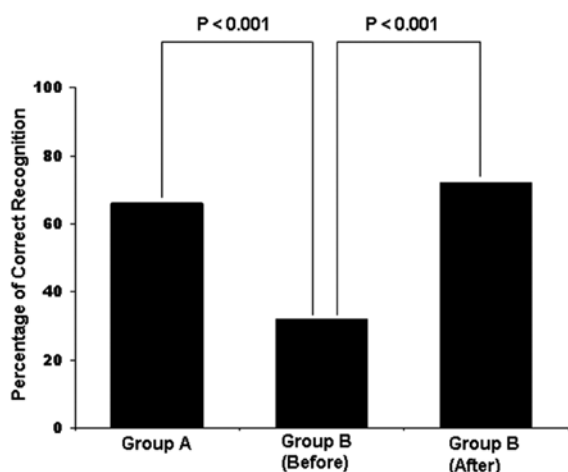


Fig. 5. Ventricular septal defect

Ryc. 5. Ubytek przegrody międzykomorowej

murmur was elevated in Group A in comparison to those in Group B (before) (88.2% vs. 65.5%, $p < 0.001$). Moreover, the authors also noted that the percentage of correct diagnoses for systolic murmur was significantly higher among the students in Group B (after) in relation to those in Group B (before) (86.3% vs. 65.5%, $p < 0.001$) (Fig. 6).

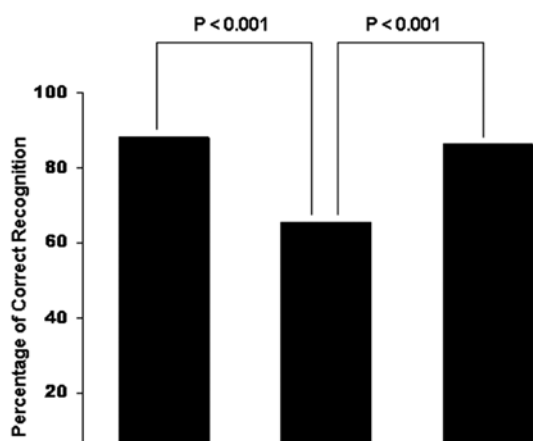


Fig. 6. Systolic murmurs

Ryc. 6. Szmerzy skurczowe

Diastolic Murmur

A total of 226 auscultations were performed on 28 patients with diastolic murmur owing to the presence of MS or AI. Half of the auscultations ($n = 113$) were completed by the students in Group A and the other half ($n = 113$) were carried out by the students in Group B (before). The percentage of making correct diagnoses for diastolic murmur was increased in Group A compared to those in Group B (before) (56.6% vs. 24.8%, $p < 0.001$). Furthermore, the authors noticed that the percentage of correct diagnoses for diastolic

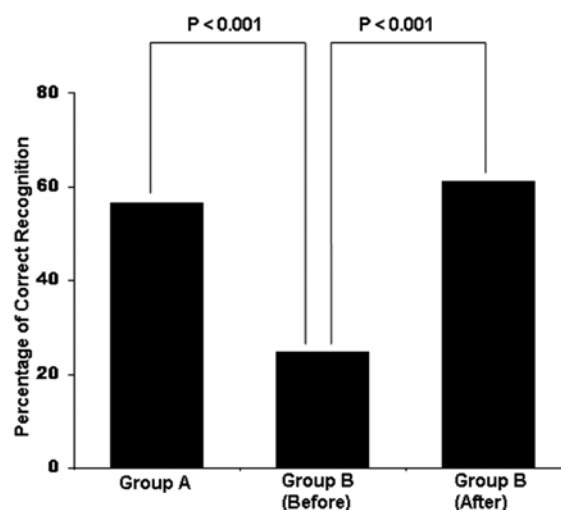


Fig. 7. Diastolic murmurs

Ryc. 7. Szmerzy rozkurczowe

murmur was notably higher among the students in Group B (after) in relation to those in Group B (before) (61.1% vs. 24.8%, $p < 0.001$) (Fig. 7).

Discussion

In the present study, the authors investigated the role of the cardiac auscultation model on the acquisition of cardiac auscultatory skills for identifying normal heart sound and murmurs arising due to MS, AI, PAS, and VSD by medical students. Overall, the current study indicated that the cardiac auscultatory skills of fifth-year medical students attending their cardiology internship were not satisfactorily efficient and the use of a cardiac simulator during the cardiac auscultatory training markedly improved their cardiac auscultatory skills.

Cardiac auscultatory skills are not easy to acquire [2, 3]. The time allocated for bedside examination has notably decreased at today's hospitals due to the heavily increased number of patients seeking healthcare and markedly decreased hospital stays [15, 16]. Cardiac auscultatory training to medical students is mostly delivered by residents whose cardiac auscultatory skills to define heart sounds and murmurs correctly are also shown to be not so effective [17]. Consequently, the cardiac auscultatory training provided to students is not quantitatively and qualitatively effective. Moreover, cardiac auscultatory training after graduation is also rarely offered to healthcare professionals whose cardiac auscultatory skills are reported to be not at the desired level during their medical education [18]. Overall, the cardiac auscultatory skills of medical students are not at desired levels and need to be improved.

The rate of appropriately diagnosing diastolic murmurs (MS and AI) among the set of all murmurs was the lowest while the percentage of correct identification of systolic murmurs were relatively better among the medical students. While the percentage of the students correctly diagnosing the murmurs owing to MS and AI was 18.9% and 21.8%, the rate of identifying the murmurs due to PAS and VSD was 45% and 32%, respectively, before the cardiac simulation training. Similar to present observations, earlier studies have reported that the cardiac auscultatory skills of medical school students and general practitioners were not adequately effective [9, 10, 19]. Although no consensus exists regarding the rate for proficient cardiac auscultatory skills in medical education, these rates are markedly under the expected levels for medical school students. In most hospitals, physicians prefer to use high tech medical devices to diagnose diseases rapidly instead of dedicating longer times for physical examination during the training of medical students [15]. The time spent for the diagnosis and treatment of a disease is inherently critical for not only patients but also doctors [20]. Increased hospital expenses are another reason forcing physicians to obtain a rapid diagnosis. Therefore, an inadequate physical skill of medical students is a significant problem of today's medical education. Alternative approaches are needed to improve the physical diagnostic skills of medical students. The use of medical simulators can help improve, at least in part, the diagnostic skills of medical students.

Cardiac auscultatory training completed at the bedside with real patients or using a cardiac simulator model increases cardiac auscultatory skills in short term memory; however, the effectiveness of this skill is unfortunately lost in long term memory [21]. Repetition of cardiac auscultatory training is required to maintain the effectiveness of cardiac auscultatory skills for long periods of time. The phrase "practice makes perfect" is utterly true for maintaining the cardiac auscultatory skills of physicians over time. A recent study reports that five hundred repetitions of cardiac auscultation can considerably improve auscultatory proficiency in recognizing basic cardiac murmurs by medical students [22]. Long term repetitions of cardiac auscultations on patients are undesirable for them and not possible in general. Since cardiac simulators are easily accessible, reliable, and capable of generating basic heart sounds and murmurs, their use as a medical education tool can be practical. The most notable feature of the cardiac simulator is its repeatability for training purpose.

Overall, in the present study the use of cardiac simulators during cardiac auscultatory training

significantly increased the cardiac auscultatory skills of medical students. Among the cardiac auscultatory skills, cardiac simulator training markedly improved the percentage of making correct diagnoses of systolic and particularly diastolic murmurs. Detection of diastolic murmurs is difficult since cardiac pathologies generate diastolic murmurs characterized by lower frequencies. In the present study, the authors noted that the use of a simulator in cardiac auscultatory training significantly increased the percentage of accurate identification of diastolic murmurs (about 25% prior to simulator training and over 50% after the simulator training). This improvement in the skills of the students suggests that the use of a simulator during auscultatory training is useful for the progression of the skills needed for correct diagnosis of diastolic murmurs, which are known to be harder than systolic murmurs to identify [9]. All of the students who joined the present study agreed to receive cardiac auscultatory training on the simulator and successfully completed the training course. The students asking for further repetitions on the simulator were later provided with cardiac auscultatory training; however, these were not recorded.

Moreover, learning by doing is shown to be a powerful pedagogical technique in medical education since it combines the five main senses; nevertheless, repeated auscultations of the patients by numerous medical students can often bother patients, and consequently the students. An auscultation model capable of making heart murmurs near to real supports the improvement of the cardiac auscultatory skills of medical students and can serve as a complementary medical training tool. Overall, the present study indicates that the use of a proper auscultation model is easier, practical and efficient in the auscultatory training of the medical students.

Although the authors did not quantitatively measure the effects of cardiac simulator training on the medical students, they observed that the students were well oriented to auscultation and showed effective contact with the patients, supporting the notion that the use of a cardiac simulator in cardiac auscultation training can strengthen the cardiac auscultatory skills of the students and help medical students become effective specialists.

Improved living conditions and increased application of preventive medicine have reduced the incidence of the diseases harming heart valves such as infectious endocarditis and acute rheumatic fever [23, 24]. Likewise, early detection and treatment of congenital heart diseases, e.g. VSD, are accessible at present due to advances in medicine [25]. Consequently, the incidence of adult pa-

tients suffering from various heart valve diseases and congenital anomalies, e.g. VSD, is lower than before. Therefore, the reduction in the number of the patients having cardiac murmurs can create a problem during the auscultation training of the medical students. The use of cardiac simulators can help overcome this problem and serve a complementary role in the training of the medical students.

Simulation-based medical training has been shown to quickly increase the skills of physical examination of medical students and enhances the concentration of teachers and trainees for the relevant issue [26, 27]. Similarly, the cardiac auscultatory skills of the medical students to correctly identify murmurs were markedly lower prior to the simulator-based cardiac auscultatory training and were considerably enhanced after the cardiac auscultatory training on the simulator. Overall, while the rate of precise identification of systolic murmurs increased two fold, diastolic murmur identification increased three fold. Besides, the use of simulation models in medical education enables the training of medical students and strengthening of their practical skills without having to have contact with real patients or in the absence of appropriate patients [28].

In conclusion, the present study indicated that

the cardiac auscultation skills of medical students are weak and the use of a cardiac simulator can improve their auscultation skills rapidly and effectively.

Study Limitations

The authors are aware of the fact that there are some limitations in the present study. One of them was that, while they studied the effectiveness of simulator-based cardiac auscultatory training on the certain pathologies causing murmurs, they did not include some other pathologies in the present study; therefore, it is hard to apply the present data to all of the murmurs generated by various cardiac pathologies. Nonetheless, simulator-based cardiac auscultatory training improved the skills of the medical students for all of the pathologies included in the present study, indicating that this training is likely to increase the skills required for correct identification of other types of murmurs. The completion of this study in only one center instead of multiple centers is the other setback of the current study. Repeating the present study with the participations of multiple centers with a larger number of participants is needed to determine the actual effectiveness of simulator-based cardiac auscultatory training.

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Conflict of interest: None declared

Received: 4.05.2012
Revised: 18.06.2012
Accepted: 12.12.2012